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José García-Quevedo,
Gabriele Pellegrino and
Maria Savona

University of Sussex

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Reviving demand-pull perspectives:
The effect of demand uncertainty and stagnancy on R&D strategy

José García-Quevedo[a], Gabriele Pellegrino[a], Maria Savona[b*]

Abstract

This paper looks at the effects of demand uncertainty and stagnancy on firms' decisions to engage in R&D activities and the amount of financial effort devoted to such activities. In so doing, the paper makes a number of contributions to the innovation literature: first, it adds to the recently revived debate on demand-pull perspectives in innovation studies by examining demand-related (lack of) incentives to invest in innovation. Second, it complements the emerging literature on barriers to innovation by focusing on demand-related obstacles rather than on the more frequently explored financial barriers. Third, it analyses whether experiencing uncertainty or lack of demand is a sector-specific feature. Firms active in high- or low-tech manufacturing or in knowledge intensive or low-tech services might be more or less dependent on demand conditions when deciding to perform R&D. We find that uncertain demand and lack of demand are perceived as two quite distinct barriers. While demand uncertainty does not seem to constrain R&D efforts, the perception of a lack of demand has a marked impact on not only the amount of investment in R&D but also the likelihood of firms engaging in R&D activities. We interpret this evidence in terms of the specific phase in the innovation cycle in which decisions to invest in R&D are taken. Sectoral affiliation does not seem to be a factor in demand conditions, supporting the conjecture that positive expectations regarding market demand are structural and necessary conditions that have to be satisfied for all firms prior to their investing in R&D.

Keywords: R&D strategy, Barriers to innovation, Demand uncertainty, Lack of demand, Innovative inputs, Panel data
JEL Classification: C23 O31 O32 O33

[a] Barcelona Institute of Economics - University of Barcelona, Barcelona.
E-mails: jgarciaq@ub.edu; gabriele-pellegrino@hotmail.it.
[*b] Corresponding author at SPRU, Science and Technology Policy Research, Jubilee Building, University of Sussex, Brighton BN1 9SL, UK. E-mail: M.Savona@sussex.ac.uk
and Faculty of Economics and Social Sciences, University of Lille 1, France.

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1. Introduction

The closely connected influences of demand and technological opportunities on the strategic decisions of firms to innovate and the aggregate outcomes of these decisions are well established subjects of research in innovation studies, since the seminal contribution of Schmookler (1966) and followed by a fierce debate among scholars in the field (Mowery and Rosenberg, 1979). A recent contribution (Di Stefano et al., 2012) reviews this debate by examining the evolution in this research, which has in turn come down in favour of either a technology-push or demand-pull source of innovation as it has sought to disentangle their relative importance in fostering innovation.

Interestingly, no previous study has analysed the demand-pull perspective from the viewpoint of barriers to innovation. As is common within the innovation literature, analyses of the factors of innovation success are proportionally more numerous than studies of patterns of failure and the effect of the lack of incentives. As such, scholars of demand-pull perspectives seem to have overlooked lack of demand or demand uncertainty as factors hampering decisions to invest in innovation.

The emerging literature on barriers to innovation has dealt primarily with the firms' characteristics that affect their perception of barriers to innovation or, when specifically examining the actual hindrances of perceived barriers, it has paid a disproportionate amount of interest to financial barriers and limitations to the financial capacity of firms to invest in R&D (see D'Este et al., 2012, and Pellegrino and Savona, 2013, for a review of this literature). This bias toward financial obstacles might well reflect the relative "dominance" of technology-push perspectives over interest in demand-related incentives to innovate.

Rather than contrasting the two perspectives empirically, here we seek to rebalance the overall picture by attempting to disentangle the effects of lack of demand, or perceived uncertainty about demand conditions, on firms' decisions to invest in R&D and the amount of resources they devote to the activity. The paper makes a number of contributions to the innovation literature: first, it adds to the recently renewed debate on demand-pull perspectives in innovation studies, by examining demand-related (i.e., lack of) incentives to invest in innovation. Second, it complements the emerging literature on barriers to innovation in two ways: on the one hand, by focusing on demand-related obstacles rather than on the more frequently explored financial barriers; and, on the other, by analyzing in detail whether experiencing demand-related obstacles is a sector-specific feature, that is, whether firms active in high- or low-tech manufacturing or in knowledge intensive or low-tech services are more or less dependent on demand conditions when deciding to perform R&D.

We find that demand uncertainty and stagnancy are two quite distinct barriers, having substantially different effects on firms' behaviour. We interpret this evidence in terms of the specific phase in the innovation cycle in which decisions to invest in R&D are formulated. While demand uncertainty has a weak, positive statistically significant effect on R&D plans, the perception of a lack of demand has a marked impact on not only the amount of investment in R&D but also the likelihood of firms engaging in R&D activities. Sectoral affiliation does not seem to be a factor in demand conditions, supporting the conjecture that positive expectations regarding market demand are a structural and necessary condition that has to be satisfied by all firms prior to deciding to invest in R&D. When considered from the perspective of barriers to innovation, demand-related incentives therefore seem to cut across sectoral specificities in technological opportunities.

In the section that follows we briefly review the two branches of literature mentioned above: that is, studies comparing demand-pull vs. technology-push sources of innovation and analyses of barriers to innovation. Section 3 describes the data employed in the empirical analysis; Section 4 illustrates the econometric strategy and the variables used in the estimations, while Section 5 discusses the results and provides a response to the main research question. Section 6 concludes.

2. Background literature

2.1. Demand-pull perspectives revisited

The innovation literature has traditionally been somewhat ambivalent with regard to the role of demand as an incentive to innovation, besides that of technological opportunities. As suggested by Di Stefano et al., (2012) in a recent review, the debate between demand-pull and technology-push perspectives has evolved through different stages, from the rigid adoption of opposing stances by the supporters of demand-pull (Schmookler, 1962, 1966; Myers and Marquis, 1969; von Hippel, 1978, 1982) and its critics (Mowery and Rosenberg, 1979; Dosi, 1982; Kleinknecht and Verspagen, 1990) before settling, more recently, for a more balanced view which sees demand as a complementary (though not dominant) factor determining innovation. This body of literature includes both conceptual and empirical contributions (Cainelli et al., 2006; Piva and Vivarelli, 2007; Fontana and Guerzoni, 2008) as well as analyses conducted at both macro- and firm-levels.

For the purposes of our discussion here, it should suffice to recall the main arguments in the debate, relate them to the most recent literature on barriers to innovation (Section 2.2) and formulate the conjectures (Section 2.3) that we then test empirically in the remaining of the paper.

As Fontana and Guerzoni (2008) suggest, the intuition regarding the influence of demand on innovation was sparked by the seminal contributions of Schmookler (1962; 1966) and Myers and Marquis (1969), who claimed that the introduction of new products and processes is conditioned by the *presence of demand* or even possibly a *latent demand* and, in general, by *positive expectations of profitability* from returns to innovation. In the absence of these conditions, firms would simply not have any incentive to innovate. Moreover, the adoption and diffusion of (especially new) products are intrinsically subject to *uncertainty*, which would further reduce incentives to innovate. The arguments forwarded by the proponents of technology-push sources touched upon various issues, ranging from the reverse causality of the empirical relationships estimated by Schmookler (1966) and Meyers and Marquis (1969) to the difficulties of identifying the relevant demand affecting innovation incentives.

It is our contention, and one we come back to later, that market size – and therefore expectations regarding profitability – and demand uncertainty are very likely to refer to different *levels* of demand. First, positive expectations with regard to profitability and, hence, incentives to innovate, despite being intrinsically linked to the fate of the new product being launched, are affected primarily by the macro-conditions of aggregate demand and the market dynamism of the specific and related products. Even incremental product or process innovation would be hard to implement if forecasts of sales and returns to innovation were poor.

Second, while uncertainty might be linked to aggregate macro-conditions of demand, it is predominantly affected by the characteristics of the new products/services and the lack of information on users and their capabilities to adopt/benefit from the new product (see also von Tunzelmann and Wang, 2003 on user capabilities).

Of course, macro- and micro-demand conditions are likely to reinforce each other, though in the case of incremental product or process innovation, aggregate stagnancy of demand might be more influential, whereas in the case of radically new products or services it is the uncertainty that is likely to play a major role in terms of incentives to innovate (see also Fontana and Guerzoni, 2008).

2.2 Demand as a barrier to innovation: stagnancy and uncertainty

Although the literature on barriers to innovation is relatively recent, scholars have found substantial evidence for the presence and effects of perceived hindrances on the propensity and intensity of engagement in innovation activities.

A large proportion of these studies have focused their attention on analyses of the effects of financial constraints on firms' cash flow sensitivity to afford R&D investments (for a review, see Schiantarelli, 1996; Hall, 2002; Bond et al., 1999; Hottenrott and Peters, 2012). Indeed, empirical evidence tends to confirm that encountering financial constraints significantly lowers the likelihood of firms engaging in innovative activities (Savignac, 2008), with this pattern being more pronounced in small firms and in high-tech sectors (Canepa and Stoneman, 2007; Hall, 2008; Hottenrott and Peters, 2012).

The implicit assumption behind this preferred focus of analysis is that it is essentially access to finance, financial uncertainty and information asymmetries that reduce the financial returns of R&D investments and the ability to attract external funds, thus reducing incentives to invest in R&D.

A few recent contributions have extended the analysis to non-financial obstacles to innovation, drawing primarily on evidence from innovation surveys, which allow the effects of knowledge-related obstacles (e.g., shortage of qualified employees, lack of information on technology and markets), market-related obstacles (e.g., lack of customer interest in innovative products, markets dominated by large incumbents), and barriers attributable to the need to fulfil national and international regulations) to be examined. Moreover, these innovation surveys allow researchers to look beyond the mere decision to invest in R&D and to take into account innovation outputs, such as the introduction of a new (to the market or to the firm) good or service or a new process.

Even within the CIS-based literature, an overwhelming number of contributions focus on the financial constraints to innovation, treating the role of non-financial constraints as a simple control factor (Tiwari et al., 2008; Mancusi and Vezzulli, 2010; Blanchard et al., 2013). Analyses of factors affecting the perception of all types of obstacles are provided, however, by Iammarino et al. (2009) and D'Este et al. (2008 and 2012). Pellegrino and Savona (2013) look at the effect of all types of barriers on the likelihood of being a successful innovator, recognizing the fundamental – possibly exacerbating – impact of other types of obstacles *indirectly* on the financial barriers and *directly* on the innovation intensity of firms. All these contributions point equally to the importance of the lack of access to finance and the lack of market responses to innovation.

2.3 Main conjectures

Overall, the implicit assumption behind the "bias" toward technology-push perspectives within the innovation literature is that firms plan their innovation investments in a context that is structurally and indefinitely capable of absorbing the outcomes of innovation, much in line with a blind trust in a sort of Say's Law[1] for innovative products. This would apply both at the general macro-economic level – that is, a general state of dynamism of aggregate consumption – and at the micro-level of analysis – that is, for the specific product/service/sector that has been introduced onto the market.

Without seeking to test the technology-push and demand-pull hypotheses empirically, here we contest this assumption and claim that if easy access to finance and the availability of funds are important conditions to *implement innovation investment plans*, trust and positive expectations regarding the state of demand are necessary conditions for firms to *enter the innovation contest* and *initiate innovation investment plans*.

Rather than focusing on market structure issues or "lack of customer interest", we turn our attention to firms' perception of the state of demand in terms of both the lack of demand *tout court* and market uncertainty. As far as the latter is concerned, we are aware that some scholars (see, for instance, Czarnitzki and Toole, 2011 and 2013)

[1] Put simply, Jean Baptiste Say claimed that "supply always creates its own demand" – i.e., markets are able to infinitely absorb any quantity of production. The Keynesian framework overall rejected Say's Law. Here we might stretch the argument and argue that in the case of innovative products, the uncertainty of whether the launch of new products or services is going to be adopted by consumers and diffused in the markets is even higher than that affecting standard plans of production.

have analysed the effect of market uncertainty on R&D investment behaviour from a real option theory perspective, finding that uncertainty causes a fall in R&D investments, albeit mitigated by patent protection (Czarnitzki and Toole, 2011) and firms' size and market concentration (Czarnitzki and Toole, 2013).

Here we take a more heuristic approach to uncertainty and one that is more data driven, with the aim of testing whether firms' self-reported perception of market uncertainty[2] affects their investment behaviour. Specifically, we examine whether the decision to invest in R&D and the amount of investment in R&D are affected by perceptions of these two demand-related obstacles over time and we empirically test this within a panel econometrics framework, as detailed in the next section.

Further, an important added value of this paper is the analysis it undertakes of possible sectoral differences in the way demand affects firms' propensity to invest in R&D[3]. Our conjecture is that service firms are substantially more sensitive to the state of demand when planning their innovative strategies. This is in line with much of the literature on innovation in services (for a review, see Gallouj and Savona, 2009), which claims that the importance of customers and user-producer interactions in services is substantially higher than in manufacturing sectors. Accordingly, we empirically test the conjectures above for both the whole sample of firms and for sub-samples of different macro-sectors, as explained in detail below.

3. Data

We draw on firm level data from the Spanish Technological Innovation Panel (PITEC), compiled jointly by the Spanish National Statistics Institute (INE), the Spanish Foundation for Science and Technology (FECYT), and the Foundation for Technical Innovation (COTEC). The data are collected in line with the Oslo Manual guidelines (OECD, 1997) and, as such, they can be considered to constitute a Community Innovation Survey or CIS-type dataset. Thus, together with general information about the firm (main industry of affiliation, turnover, employment, founding year), PITEC also includes a (much larger) set of innovation variables that measure the firms' engagement in innovation activity, economic and non-economic measures of the effects of innovation, self-reported evaluations of factors hampering or fostering innovation,

[2] As explained in Section 3, information on market uncertainty is based on responses to a specific question formulated in terms of whether "uncertain demand for innovative goods or services" is perceived as a barrier to innovation. We believe that despite the qualitative, self-report nature of the information provided by this question (in common with all CIS-based evidence), it allows us to draw a plausible picture of firms' responses to increasing levels of (perceived) uncertainty.

[3] In the best tradition of innovation studies, this allows us to control for the role of different technological opportunities at the sectoral level and, therefore, to implicitly account for the "technology-push" argument.

participation in cooperative innovation activities and some complementary innovation activities such as organisational change and marketing[4].

An important feature that distinguishes PITEC from the majority of European CIS-type datasets is its longitudinal nature. Since 2003 systematic data collection has ensured the consistent representativeness of the population of Spanish manufacturing and service firms over a number of time periods.

In this study we use data for the period 2004-2011 and select our working database from the initial sample (100,016 firm-year observations). First, we discard all firms operating in the primary (1,628 observations), construction (3,914 observations), utilities (720 observations) and sewage/refuse disposal (318 observations) sectors and all firms involved in M&A transactions (8,543 observations)[5]. In line with our previous work (D'Este et al., 2008 and 2012; Pellegrino and Savona, 2013), we then select a relevant sample. To this end, we exclude 6,114 observations that refer to "non innovation-oriented firms", i.e., firms that did not introduce any type of innovation (goods, services or processes) and which at the same time did not encounter any barriers to innovation during the three-year period, and which we therefore infer are not interested in innovating. The resulting sample of 78,779 firm-year observations is further reduced by excluding all the missing values for the variables used in the empirical analysis (24,315 observations), as well as 354 firms that were observed for just one year.

Table 1 shows the composition of the final dataset following data cleaning. As can be seen, half of the 9,132 firms (54,110 observations) included in the final sample are observed for all eight periods (2004-2011); about 23% are observed for seven periods while only a negligible percentage of firms (around 10%) are observed for less than five years. These figures allow us to confirm with confidence the suitability of this dataset for the subsequent dynamic analysis.

Table 1. Composition of the panel

Time obs.	N° of firms	%	% Cum	N° of obs.
2	384	4.26	4.26	768
3	511	5.55	9.81	1,533
4	647	7.08	16.89	2,588
5	893	9.85	26.74	4,465
6	2,123	23.25	49.99	12,738
7	4,574	50.01	100.00	32,018
Total	9,132	100		54,110

[4] Recent works based on the use of this dataset are López-García, et al. (2013), D'Este et al (2014) and Segarra and Teruel (2014)

[5] It is common practice in the innovation literature to focus on private manufacturing and services companies and to exclude public utilities and primary activities owing to differences in the regulatory framework in which they operate. In the case of M&A transactions, firms were eliminated from the sample in the years following the merger or acquisition.

Note: the final sample only comprises firms for which a lag of the dependent variable is available. This implies that t=2 refers to firms that are observed for at least three periods, t=3 corresponds to firms that are observed for four periods and so on.

4. Econometric strategy and variables

As discussed above, the main aim of this paper is to assess empirically whether and, if so, how demand-related obstacles to innovation affect two important innovative decisions taken by firms: their propensity to engage in R&D and, conditional on that, the level of investment in R&D. As stressed by a largely consolidated stream of literature, innovation and, in particular, R&D activities are processes that present high degrees of cumulativeness and irreversibility and, as a result, are characterised by a high level of persistence (see Atkinson and Stiglitz, 1960; David, 1985; Dosi, 1988; Cefis and Orsenigo, 2001). This evidence is fully supported by our data. Indeed, if we examine the transition probabilities of engaging in R&D activities (see Table 2) it emerges that almost 86% of R&D performers in one year retained this same status during the subsequent year. This percentage rises to 91% in the case of non R&D performers that did not change their status into the next period.

Table 2. Transition probabilities: R&D performers

Performer in t-1	Performer in t	
	R&D	
	0	1
0	90.95	9.05
1	14.15	85.85
Total	43.98	56.02

This evidence suggests that the use of an autoregressive specification for the two decisions taken by a firm in relation to its R&D activities is the most suitable. Accordingly, our empirical strategy is based on the estimation of the following two equations:

$$y^*_{1it} = \varphi_1 y_{1i,t-1} + \beta_1^{'} x_{it} + c_{1i} + v_{1it} \qquad (1)$$

$$y^*_{2it} = \varphi_2 y_{2i,t-1} + \beta_2^{'} x_{it} + c_{2i} + v_{2it} \qquad (2)$$

where y^*_{1it} and y^*_{2it} denote the two latent dependent variables representing respectively firm *i*'s propensity at period *t* (*i* = 1,…N; *t* = 1,….T) to engage in R&D (expressed as a binary variable), and firm *i*'s decision regarding the level of investment to make in R&D activity (the natural logarithm of R&D expenditure). For each firm *i*, $y_{1i,t-1}$ and

$y_{2i,t-1}$ represent the one-period lag of the y^*_{1it} and y^*_{2it} dependent variables, while x is a vector of explanatory variables that has been chosen taking into account both the characteristics of the dataset at our disposal and the main insights provided by the literature on the subject.

More specifically, we first consider a binary indicator of *international competition*, which is equal to 1 if a firm's most significant market of destination is international and equal to 0 otherwise. On the grounds that international markets tend to be characterized by a higher level of competition, this variable should exert a positive effect on the firm's propensity to innovate (e.g., Archibugi and Iammarino, 1999; Narula and Zanfei, 2003; Cassiman *et al.*, 2010). However, some authors (see, for example, Clerides *et al.*, 1998) warn of the possible existence of a reverse causation: most innovative firms are more likely to penetrate foreign markets and self-select themselves so as to engage in tougher foreign competition. In order to deal with this endogeneity issue we consider the one-period lagged value of this variable.

Reverse causation has also been observed in the relationship between *public subsidies* and innovation activity. Most of the literature on the subject provides empirical support for the positive impact of incentive schemes on a firm's propensity to both engage in and undertake R&D (see, for example, Callejon and García-Quevedo, 2005; González *et al.,* 2005 for the Spanish case). However, other contributions cast some doubt on the reliability of such a relationship because of the potential endogeneity of public funding (see, for example, Wallsten, 2000). Accordingly, the t-1 value of an indicator of whether the firm has received public support for innovation is included.

A one-period lagged value has also been considered for two indicators of whether the firm makes use respectively of *patents* and *informal methods* (registration of design, trademarks, copyrights) to protect its innovations[6]. In this case, the rationale is that the positive impact of the mechanisms of appropriability used by a firm take time to make themselves manifest.

We also use a variable recording a firm's *age* to control for age related effects. The theoretical and empirical literatures provide mixed evidence regarding the possible effect of age on engagement in/realization of innovation activities. Klepper (1996) provides a theoretical model that points to a negative relationship between a firm's age and its probability of innovating. However, as Galande and De la Fuente (2003) point out, a firm's age can also be seen as a proxy of the firm's knowledge and experience accumulated over time and, consequently, it should be positively related to innovation.

Moreover, in line with various studies that stress the expected innovative benefits for a firm that is a *member of an industrial group* (see Mairesse and Mohnen, 2002), such as easier access to finance and positive intra-group knowledge spillovers, we include a dummy variable identifying this characteristic.

A further important factor that might influence a firm's R&D decision is the business cycle. In order to control for this aspect, in line with some recent contributions

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[6] Previous studies generally show a clear-cut, positive link between these factors and a firm's innovative activity (see Levin *et al.*, 1987; Salomon and Shaver, 2005; Liu and Buck, 2007).

(see Aghion et al., 2012; Lopez Garcia et al., 2013), we use a micro-level perspective to identify idiosyncratic shocks to firms by considering *firm's sales growth*.

Finally, following the Schumpeterian tradition, we consider a variable reporting the log of the total number of employees as a measure of *firm size* and a set of *industry dummies* variables (based on the 2-digit CNAE codes[7]).

In the case of the demand-related obstacles, in line with the discussion in Section 2 and the rationale underpinning this, we single out two binary variables that identify an increase (over a yearly base) in the degree of importance (irrelevant, low, medium, high) that the firms assign to the following two barriers specified as "uncertain demand for innovative goods and services" and "lack of demand for innovation"[8]. Finally, we control for possible additional negative effects of *other obstacles* to innovation, including a dichotomous variable recording an annual increase in the importance of the firm's level of perception of the remaining obstacle categories (cost and knowledge related obstacles, market dominated by established firms). Table A1 in the Appendix shows the list of variables, their acronyms and a detailed description.

As for the econometric methodology, in order to estimate equations (1) and (2), we apply the method proposed by Wooldridge (2005) based on a conditional maximum likelihood estimator. The author proposes a simple solution in order to address the two well-known problems that might bias the results in a dynamic random effects probit/tobit context: the initial condition problem and the correlation between the individual error term and the explanatory variables. Specifically, Wooldridge suggests modelling the firm-specific error term as follows:

$$c_{ji} = \alpha_{j0} + \alpha_{j1} y_{ji0} + \alpha_{j2} \bar{x}_i + a_{ji} \qquad (3)$$

where $\bar{x}_i$ refers to the within mean of the x_{it} vector of explanatory variables and embodies the elements that are correlated with x_{it}, while y_{ji0} (with j = 1,2) are the initial conditions of the dependent variables that are supposed to be correlated with the individual error term.

The new equations (1) and (2), obtained by replacing the individual error terms c_{ji} (with j= 1,2) in the right-hand side of equation 3, are estimated using standard random effects probit (equation (1)) and tobit (equation (2), due to the censored nature of R&D expenditure) software.

[7] The Spanish industrial classification codes (CNAE) correspond to the European NACE taxonomy.

[8] We opted to use these constructed variables in light of the high within-variation of the obstacle variables. However, by construction, the variables take the value 0 in the case of firms persistently assessing the two barriers as highly relevant. We therefore perform robustness checks by considering instead two dichotomous variables taking the value 1 when a firm evaluates as highly relevant the lack/uncertainty of demand and 0 otherwise. The results shown in tables A3-A4 and A5 in the Appendix are remarkably consistent with those discussed in Section 5.2.

5. Empirical evidence

5.1. Descriptive statistics

One of the conjectures forwarded in this paper is that a firm's sectoral affiliation is a major determinant of the nature and dimension of the effects of demand obstacles on its innovative behaviour. Following the classification proposed by Eurostat and based on an aggregation of NACE manufacturing and service sectors, we identify four macro-categories: high/medium-high tech manufacturing industries (HMHt), low/medium-low tech manufacturing industries (LMLt), knowledge-intensive services sectors (KIS) and less knowledge-intensive services sectors (LKIS). Table 3 depicts the sectoral (2 digit) composition and the distribution of these four macro-categories and reports the mean of the two demand obstacle variables *Lack of demand* and *Uncertainty* for each sector. In terms of sectoral composition, there is a slight prevalence of LMLt firms, constituting 35% of the total observations, while the remaining 65% of the observations are roughly equally distributed among the three other sectoral categories (HMHt, KIS and LKIS). If we consider the sectoral frequencies in terms of the macro-categories, around 22% of the LMLt firms operate in the food, beverage and tobacco sectors; around 29% of HMHt companies are active in the chemical sectors; 35% of KIS firms carry out computer programming activities and, finally, 36% of the LKIS firms are active in the trade sector. Across these four macro-sectors, almost 20% of firms have experienced an increase in the degree of importance assigned to demand uncertainty, while a lower percentage (around 16%) experienced an increase in the degree of importance of the lack of demand as a perceived obstacle. In the case of the sectoral categories, no striking differences can be found, with a percentage range running from 13.54 (HMHt) to 17.90 (LKIS) for the *Uncertainty* variable and from 17.39 (HMHt) to 22.26 (LKIS) for the *Lack of demand* variable. Overall, these figures reveal a quite high responsiveness on the part of firms to changes in the demand condition that can hamper their innovation activities. This evidence is further corroborated by the figures in Table 4, which report the mean values (in percentages) of the two demand-related obstacles by year and sectoral categories. As is apparent, though, these variables show considerable within variation.

Table 3. Sectoral composition for macro categories (relative frequencies) and percentage of firms that experienced an increase in the degree of importance of the demand (uncertainty and lack) related obstacles

	Freq. For category	% over category	% over total	Incr. in lack of demand	Incr. in uncertainty demand
Low/Med-Low	18,730	100.00	34.61	16.27	19.87
Petroleum	39	0.21	0.07	10.26	20.51
Food products beverages, tobacco	4,109	21.94	7.59	16.50	19.96
Textiles	1,180	6.30	2.18	13.90	16.86

	Freq. For category	% over category	% over total	Incr. in lack of demand	Incr. in uncertainty demand
Wearing apparel	370	1.98	0.68	14.32	24.32
Leather -products, footwear	359	1.91	0.66	19.50	18.38
Wood-products, cork	599	3.20	1.11	20.03	24.71
Pulp/paper-products	546	2.92	1.01	13.00	16.12
Rubber and plastics	1,981	10.57	3.66	14.89	19.59
Mineral products (no metallic)	1,736	9.27	3.21	17.40	20.68
Basic metals	955	5.10	1.76	16.65	20.52
Fabricated metal products	3,464	18.49	6.40	17.26	20.84
Furniture	1,119	5.98	2.07	18.77	21.00
Other manufacturing n.e.c.	1,835	9.80	3.39	14.39	18.37
Repair of fabricated metal products	438	2.34	0.81	13.47	19.86
High/Med-High	11,736	100.00	21.69	13.54	17.39
Chemicals	3,364	28.67	6.22	12.90	16.59
Pharmaceutical	909	7.75	1.68	10.34	16.50
Electronic, optical, computer products	1,049	8.94	1.94	12.96	17.35
Electrical equipment	1,265	10.77	2.34	13.20	18.02
Other machinery	3,540	30.17	6.54	15.31	17.91
Motor vehicles	1,274	10.86	2.35	13.19	18.29
Aerospace	143	1.21	0.26	13.29	15.38
Other transport equipment	192	1.64	0.35	15.10	17.71
KIS	11,942	100.00	22.07	15.26	19.58
Telecommunications	312	2.61	0.58	13.46	22.12
Computer programming activities	4,207	35.24	7.77	15.43	20.25
Other inform. and communication serv.	951	7.96	1.76	18.30	22.08
Financial intermediation, insurance	1,086	9.09	2.01	15.29	17.03
Research and development services	1,678	14.05	3.10	11.98	17.10
Other activities*	3,505	29.34	6.48	19.60	19.80
Education	203	1.70	0.38	15.76	20.20
LKIS	11,702	100.00	21.63	17.90	22.26
Trade	4,236	36.20	7.83	16.34	20.87
Passenger transport, warehousing	1,153	9.86	2.13	20.29	23.42
Hotels and Restaurants	708	6.04	1.31	17.37	23.73
Real Estate	317	2.71	0.59	19.87	22.71
Public administration and auxiliary serv.	3,186	27.22	5.89	17.92	23.07
Other service activities**	2,102	17.97	3.88	8.52	22.65
TOTAL	54,110		100.00	15.81	19.78

* Legal activities; Activities of head offices; Architectural activities; Advertising agencies; Specialised design activities; Veterinary activities.

** Washing and (dry-)cleaning of textile and fur products; Repair of computers and peripheral equipment.

Table 4. Percentage of firms that report an increase in the degree of importance of the demand (uncertainty and lack) related obstacles. (by year and sectoral categories)

	2005		2006		2007		2008		2009		2010		2011	
	Un. Dem.	Lack Dem.	Un. Dem.	Lack Dem.	Un. Dem.	Lack Dem.	Un. Dem.	Lack Dem.	Un. Dem.	Lack Dem.	Un. Dem.	Lack Dem.	Un. Dem.	Lack Dem.
Low/Med-Low	24.07	18.80	19.92	16.80	19.14	13.91	20.50	17.25	19.15	15.33	18.58	16.73	17.98	15.44
High/Med-High	20.00	16.91	17.69	13.32	17.00	11.98	18.07	14.23	16.90	11.54	16.79	13.88	15.25	13.38
KIS	24.37	17.76	20.86	15.47	19.17	14.59	19.96	16.27	17.74	15.45	17.36	14.23	18.38	13.27
LKIS	26.57	20.28	23.52	20.57	20.37	15.28	25.11	18.16	20.36	17.86	19.87	16.54	20.43	16.88
Total	23.73	18.47	20.40	16.54	18.95	13.94	20.87	16.59	18.61	15.09	18.21	15.51	18.03	14.84
Observations	6,616		8,524		8,439		8,229		7,931		7,459		6,912	

Our examination of possible sectoral specificities in terms of a firm's characteristics (see Table 5 for the summary statistics – mean and standard deviation – of the variables presented above) reveals that some of the differences are in line with expectations. Specifically: 1) HMHt and KIS firms appear to be more likely to engage in R&D, to invest more in R&D and to have a higher probability of receiving subsidies for their innovation activity (in line with the previous discussion) than do the other two categories; 2) firms in the manufacturing sectors show a much higher propensity to export than those active in the services sectors; 3) while no striking sectoral differences emerge with respect to the firm's propensity to use informal methods of protection (the lowest percentage being associated, as expected, with LKIS firms), HMHt firms are much more likely to protect the results of their innovation activity by means of patents than are the firms operating in the other sectors (with only 5% of LKIS firms resorting to appropriability methods of this type). If we examine the remaining variables, on average 37% of the observations refer to firms that are part of an industrial group: this percentage ranges from 34% for firms in the LMLt category to 42% for those in the MHMt group. Finally, turning to the variable ln(Size) and ln(Age), on average, firms acting in the KIS sectors appear to be younger and smaller than their counterparts in the other sectoral categories[9].

[9] It is worth nothing that, since we use panel data, the revealed negative relationship between R&D and age might be due to a survivorship bias. Indeed, as the subsequent surveys can only account for firms that have survived until the date of data collection, the probability that the resulting sample may be biased towards the more successful companies is not negligible. This could be particularly true for new born and young firms which are more likely to be affected by early failure.

Table 5. Descriptive statistics: mean and standard deviation of the variables; all firms and 4 sectoral categories

	All firms		*Low/Med-low*		*High/Med-high*		*Kis*		*Lkis*	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
ln(R&D)	7.20	6.21	6.92	6.05	9.62	5.52	8.43	6.17	3.95	5.67
R&D dummy	0.58	0.49	0.58	0.49	0.77	0.42	0.66	0.47	0.33	0.47
R&D dummy t-1	0.63	0.48	0.63	0.48	0.80	0.40	0.70	0.46	0.37	0.48
Lack of demand	0.16	0.36	0.16	0.37	0.14	0.34	0.15	0.36	0.18	0.38
Uncertainty	0.20	0.40	0.20	0.40	0.17	0.38	0.20	0.40	0.22	0.42
ln(Age)	3.06	0.65	3.19	0.62	3.20	0.63	2.77	0.66	3.02	0.61
Exporter dummy t-1	0.63	0.48	0.77	0.42	0.85	0.36	0.43	0.50	0.37	0.48
Industrial group	0.37	0.48	0.34	0.47	0.42	0.49	0.35	0.48	0.39	0.49
Patent dummy t-1	0.13	0.33	0.13	0.33	0.20	0.40	0.13	0.33	0.05	0.22
Informal protection dummy t-1	0.24	0.43	0.25	0.44	0.27	0.44	0.26	0.44	0.18	0.38
ln(Size)	4.10	1.56	4.05	1.29	4.08	1.34	3.66	1.67	4.65	1.87
Subsidy dummy t-1	0.37	0.48	0.35	0.48	0.42	0.49	0.48	0.50	0.22	0.42
Sales growth	0.00	0.59	-0.01	0.42	0.00	0.51	0.02	0.78	0.00	0.66
Other obstacles	0.47	0.50	0.48	0.50	0.45	0.50	0.47	0.50	0.46	0.50
Observation	54,110		18,730		11,736		11,942		11,702	

Table 6 reports the mean values of the variables for the four different firm types identified by taking into account their "demand obstacle status". More specifically we distinguish those firms that did not experience an increase in the degree of relevance assigned to either of the two obstacles, from those that report an increase in the degree of importance of only the *lack of demand* obstacle; only the *uncertainty* demand obstacle; or both types of demand obstacle. We find that firms belonging to the first category appear to present quite distinct characteristics from those presented by firms in any of the remaining groups. Specifically, firms that did not report any increase in the degree of relevance assigned to either of the two obstacles present higher values for all the variables considered, with the exception of the variables of *other obstacles* and *sales growth*. In contrast, and as expected, firms presenting positive values for the demand obstacle variables appear to be less R&D oriented (both in terms of the probability of conducting the activity and the level of investment) than their counterparts, and this is particularly true in the case of firms that report an increase in the level of importance of the *lack of demand* obstacle. This evidence is largely robust across the four sectoral categories. Albeit solely at the descriptive level, this evidence seems to suggest that, regardless of the sector, demand conditions play an important role in affecting innovative firms' decisions. We test this in an econometric framework in the next section.

Table 6. Descriptive statistics: mean of the variables by sectoral categories and by obstacles variables status (whole sample, LMLt, HMHt)

	All the sample				*Low/Med-low*				*High/Med-high*			
	No-obst.	*Uncer. Dem.*	*Lack of Dem.*	*Both Obst*	*No-obst.*	*Uncer. Dem.*	*Lack of Dem.*	*Both Obst*	*No-obst.*	*Uncer. Dem.*	*Lack of Dem.*	*Both Obst*
ln(R&D)	7.65	6.87	5.34	5.57	7.36	6.70	5.11	5.37	10.01	9.35	7.43	8.15
R&D dummy	0.62	0.56	0.44	0.46	0.61	0.55	0.43	0.46	0.79	0.74	0.61	0.67
R&D dummy t-1	0.65	0.58	0.56	0.54	0.65	0.58	0.57	0.55	0.82	0.77	0.73	0.73
ln(Age)	3.08	3.01	3.01	3.04	3.20	3.14	3.14	3.18	3.22	3.16	3.16	3.14
Lack of demand	0	0	1	1	0	0	1	1	0	0	1	1
Uncertainty	0	1	0	1	0	1	0	1	0	1	0	1
Exporter dummy t-1	0.65	0.59	0.58	0.56	0.78	0.74	0.73	0.70	0.86	0.83	0.82	0.78
Industrial group	0.38	0.35	0.33	0.35	0.35	0.33	0.28	0.31	0.43	0.41	0.36	0.39
Patent dummy t-1	0.13	0.11	0.11	0.10	0.13	0.12	0.11	0.10	0.20	0.17	0.17	0.17
Informal protection dummy t-1	0.25	0.22	0.22	0.20	0.26	0.24	0.23	0.22	0.28	0.25	0.23	0.24
ln(Size)	4.14	4.05	3.94	4.06	4.10	3.99	3.81	3.96	4.12	4.07	3.87	3.91
Subsidy dummy t-1	0.38	0.35	0.33	0.32	0.36	0.33	0.32	0.33	0.42	0.42	0.37	0.37
Sales growth	0.00	0.01	-0.03	-0.01	-0.01	-0.01	-0.05	0.00	0.01	0.01	-0.02	-0.03
Other obstacles	0.40	0.60	0.74	0.54	0.41	0.61	0.74	0.54	0.39	0.64	0.73	0.51
Observation	38,244	7,313	5,161	3,392	13,198	2,485	1,811	1,236	8,733	1,414	962	627
%	70.68	13.52	9.54	6.27	70.46	13.27	9.67	6.60	74.41	12.05	8.20	5.34

5.2. Econometric results

The estimation results for the propensity to engage in R&D (probit estimations) and for the amount of expenditure dedicated to R&D (tobit estimations) for the whole sample are reported in Table 7. The table shows the estimated parameters of the main variables of interest, the demand obstacles, and the control variables.

The results for the control variables present the expected signs and significance. First, both R&D decisions (whether or not to invest and how much to invest) appear to be highly persistent over time as the parameters for the initial value and the lagged dependent variables are positive and highly significant. Second, in both estimations, the traditional firm characteristics affecting decisions related to R&D expenditure present the expected sign. Larger firms that conduct business internationally are more likely to carry out R&D activities and to devote more resources to them. Moreover, although the literature is not unanimous on this point, our results suggest that there is a negative and significant relationship between age and R&D, so that younger firms are more likely to carry out R&D activities. Third, other variables that characterise the innovation behaviour of firms, including the use of intellectual property rights and being recipients of public subsidies, also have a positive effect on R&D investments. Finally, while firms with higher levels of sales growth are more likely to engage in R&D and to invest more in R&D, the increase in the perception of other obstacles to innovation exerts, as expected, a negative and highly significant effect on both decisions taken by the firm.

The results of the estimations (Tables 8 and 9) are consistent with most of the previous results regarding the effect and significance of the control variables across the four groups of sectors. The parameters for the initial conditions and the lagged dependent variables are positive and significant showing that the likelihood of carrying out R&D and R&D investment are highly persistent across different sectors. In addition, as in the estimation for the full sample, size and participation in foreign markets present a positive relationship with the decision to engage in R&D and the level of investment. Public subsidies also show positive and significant parameters across the four groups of sectors. On the other hand, age is only significant in the less knowledge-intensive services, showing a negative link as in the full-sample estimation. Finally, the negative effect of the variable controlling for other obstacles is particularly important in high and medium-high technology manufacturing sectors and in knowledge-intensive sectors.

5.2.1 Uncertainty, lack of demand and R&D strategies

Turning to our main variables of interest, we find that an increase in the level of demand uncertainty for innovative goods or services as perceived by firms does not affect their R&D decisions and presents a weak positive relation to the amount of R&D invested. In particular, in the sectoral estimations the parameter is not significant and, therefore, an increase in uncertainty neither affects the likelihood of engaging in R&D nor the amount invested in these activities.

As discussed in Section 2, the theoretical literature examining the relationship between uncertainty and R&D does not offer a conclusive answer. The few empirical studies in this field seem to support a negative relationship (Czarnitzki and Toole, 2011 & 2013), while in some recent research work (Stein and Stone, 2013) a positive relationship between uncertainty and R&D investment has been found, which seems to be (weakly) supported by our full-sample estimations. Our results suggest that there might be a defensive strategy in response to an increase in perceived demand uncertainty in terms of firms' opting to invest or opting to devote more of their budget to R&D.

The weakly positive relation between uncertainty and R&D behaviour might be explained by a "caution effect" that leads to a reduction in the responsiveness of R&D to changes in business conditions when uncertainty is higher (Bloom, 2007; Bloom et al., 2007). Overall, our findings support the (robust) evidence on the persistence over time of R&D activities (see also Cefis and Orsenigo, 2001): decisions to invest in R&D therefore seem to belong to firms' structural, long-term strategies. After all, particularly when investing in basic research and in the first phases of applied research, returns to R&D are themselves almost by definition highly uncertain and in most cases highly risky. Part of the demand uncertainty might therefore be already "incorporated" in the strategic horizon of firms' decisions and may even be considered an incentive to face uncertainty by competing in terms of product quality.

In contrast with this result, and interestingly for the purpose of our analysis, the firms' perception of deterioration in demand conditions has a strong and significantly negative effect on R&D strategy. Falling or the lack of demand for goods and services not only has a negative effect on the amount invested in R&D but also reduces the likelihood of engaging in R&D altogether[10]. Although a general stagnation of demand may affect prices and therefore lead to a net increase in demand for cheaper innovative products (OECD, 2012), our results show that the negative effect is clearly dominant, suggesting that rather than uncertainty with regard to the demand for a single product or for a specific portfolio of products, it is the general macro-economic condition and, therefore, expectations regarding the aggregate state of the economy that affect firms' R&D strategies. This confirms our conjecture that, especially in time of crisis, demand-pull perspectives on innovation should be revisited and made better use of for (macro) policy purposes. We will return to these considerations in the concluding section.

[10] Even when considering the joint effect of the increase in lack and uncertainty of demand, as shown in Table 2A in the appendix, it clearly emerges that the negative effect of the perceived lack of demand dominates over uncertainty, as the net effect is still negative.

Table 7. Dynamic RE probit and tobit estimations for the whole sample

	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)
R&D Dummy t-1	0.263***		0.268***	
	(0.005)		(0.005)	
R&D Dummy t_0	0.229***		0.219***	
	(0.008)		(0.008)	
Ln (R&D) t-1		0.696***		0.701***
		(0.010)		(0.010)
Ln (R&D) t_0		0.469***		0.458***
		(0.013)		(0.013)
Uncertainty	0.002	0.146**		
	(0.004)	(0.066)		
Lack of demand			-0.070***	-1.256***
			(0.004)	(0.074)
ln(Age)	-0.003	-0.169**	-0.003	-0.173**
	(0.004)	(0.078)	(0.004)	(0.077)
Exporter dummy t-1	0.061***	0.984***	0.060***	0.967***
	(0.005)	(0.086)	(0.005)	(0.085)
Industrial group	0.013***	0.118	0.013***	0.124
	(0.005)	(0.090)	(0.005)	(0.089)
Patent dummy t-1	0.039***	0.228**	0.039***	0.225**
	(0.007)	(0.095)	(0.007)	(0.094)
Informal protection dummy t-1	0.033***	0.478***	0.031***	0.463***
	(0.005)	(0.073)	(0.005)	(0.073)
ln(Size)	0.036***	0.575***	0.034***	0.558***
	(0.002)	(0.036)	(0.002)	(0.036)
Subsidy dummy t-1	0.053***	0.569***	0.052***	0.562***
	(0.004)	(0.069)	(0.004)	(0.068)
Sales growth	0.019***	0.315***	0.018***	0.305***
	(0.003)	(0.044)	(0.003)	(0.044)
Other obstacles	-0.024***	-0.260***	-0.017***	-0.143***
	(0.003)	(0.054)	(0.003)	(0.054)
Constant		-8.560***		-8.156***
		(0.350)		(0.345)
N° of observations	54,110	31,558	54,110	31,558
Log likelihood	-18,349.36	-110,152.19	-18,230.76	-115,420.97
σ_u	0.829***	3.286***	0.804***	7.466***
	(0.025)	(0.063)	(0.025)	(0.080)
ρ	0.407***	0.311***	0.393***	0.700***
LR test for Rho	741.549	2,759.567	676.358	8,805.801
p-value	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets. Time and industry dummies are included. Columns 1-3 report marginal effects.

5.2.2 Uncertainty, lack of demand and R&D strategies – sectoral specificities

The estimations carried out for the four groups of sectors (Tables 8 and 9), distinguishing between manufacturing and service sectors as well as their respective technological content, show that the effect of demand obstacles on R&D investments are homogenous across sectors. Our results are therefore robust, confirming that demand conditions affect the R&D behaviour in all types of firm, regardless of their sectoral affiliation. High demand uncertainty neither affects the likelihood of performing R&D nor the amount invested in it, in any of the four sectors. In contrast, deterioration in general demand conditions has a negative effect across all four sectors. However, the magnitude of these effects is not homogeneous across all sectors. In particular, the reduction in demand has a more intense effect on expenditure in R&D in the less knowledge-intensive services.

Table 8. Dynamic RE probit and tobit estimations for Manufacturing sectors (Low/medium and High/medium tech sectors)

	Low/medium-low tech Sectors				High/medium-high tech Sectors			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
R&D Dummy t-1	0.299***		0.303***		0.215***		0.220***	
	(0.009)		(0.009)		(0.012)		(0.012)	
R&D Dummy t_0	0.236***		0.225***		0.183***		0.174***	
	(0.015)		(0.015)		(0.017)		(0.017)	
Ln (R&D) t-1		0.723***		0.729***		0.652***		0.657***
		(0.017)		(0.018)		(0.018)		(0.018)
Ln (R&D) t_0		0.425***		0.414***		0.301***		0.292***
		(0.022)		(0.022)		(0.023)		(0.023)
Uncertainty	0.001	0.184			0.001	0.084		
	(0.007)	(0.118)			(0.007)	(0.105)		
Lack of demand			-0.082***	-1.401***			-0.060***	-1.038***
			(0.008)	(0.133)			(0.008)	(0.120)
ln(Age)	0.000	-0.052	0.001	-0.047	0.001	-0.093	0.001	-0.093
	(0.008)	(0.131)	(0.007)	(0.129)	(0.008)	(0.114)	(0.008)	(0.112)
Exporter dummy t-1	0.083***	1.544***	0.080***	1.525***	0.058***	1.004***	0.056***	0.980***
	(0.009)	(0.166)	(0.009)	(0.165)	(0.010)	(0.162)	(0.010)	(0.160)
Industrial group	0.032***	0.403**	0.031***	0.405**	-0.014	-0.270*	-0.014	-0.261*
	(0.010)	(0.163)	(0.010)	(0.161)	(0.010)	(0.143)	(0.010)	(0.142)
Patent dummy t-1	0.051***	0.429**	0.049***	0.413**	0.025**	0.111	0.026**	0.120
	(0.012)	(0.170)	(0.012)	(0.169)	(0.011)	(0.128)	(0.011)	(0.127)
Informal protection dummy t-1	0.035***	0.503***	0.033***	0.484***	0.037***	0.453***	0.036***	0.442***
	(0.009)	(0.133)	(0.009)	(0.132)	(0.009)	(0.112)	(0.009)	(0.112)
ln(Size)	0.064***	1.025***	0.062***	0.993***	0.049***	0.697***	0.047***	0.676***
	(0.005)	(0.075)	(0.004)	(0.074)	(0.005)	(0.068)	(0.005)	(0.067)
Subsidy	0.043***	0.460***	0.043***	0.461***	0.034***	0.264***	0.034***	0.264***

	Low/medium-low tech Sectors				High/medium-high tech Sectors			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
dummy t-1	(0.007)	(0.118)	(0.007)	(0.118)	(0.008)	(0.102)	(0.007)	(0.101)
Sales growth	0.020***	0.369***	0.019***	0.359***	0.013**	0.260***	0.012**	0.244***
	(0.007)	(0.115)	(0.007)	(0.114)	(0.005)	(0.079)	(0.005)	(0.079)
Other obstacles	-0.013**	-0.080	-0.006	0.045	-0.042***	-0.442***	-0.037***	-0.363***
	(0.006)	(0.097)	(0.006)	(0.097)	(0.006)	(0.084)	(0.006)	(0.083)
Constant		-10.892***		-10.493***		-4.502***		-4.175***
		(0.703)		(0.691)		(0.673)		(0.662)
N° of observations	18,730	10,774	18,730	10,774	11,736	8,985	11,736	8,985
Log likelihood	-6,962.85	-38,630.89	-6,906.97	-38,575.79	-3,444.10	-27,914.75	-3,414.47	-27,877.33
σ_u	0.813***	3.398***	0.783***	3.318***	0.896***	2.375***	0.857***	2.318***
	(0.039)	(0.111)	(0.039)	(0.112)	(0.061)	(0.097)	(0.061)	(0.097)
ρ	0.398***	0.297***	0.380***	0.288***	0.446***	0.278***	0.423***	0.268***
LR test for Rho	279.950	935.581	250.348	885.615	148.184	604.328	129.396	566.990
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets. Time and industry dummies are included. Columns 1-3-5-7 report marginal effects.

Table 9. Dynamic RE probit and tobit estimations for services sectors (KIS and LKIS)

	KIS				LKIS			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
R&D Dummy t-1	0.275***		0.278***		0.233***		0.237***	
	(0.011)		(0.011)		(0.010)		(0.010)	
R&D Dummy t_0	0.175***		0.168***		0.244***		0.234***	
	(0.017)		(0.017)		(0.016)		(0.016)	
Ln (R&D) t-1		0.715***		0.717***		0.773***		0.782***
		(0.020)		(0.020)		(0.032)		(0.032)
Ln (R&D) t_0		0.336***		0.330***		0.804***		0.784***
		(0.024)		(0.024)		(0.044)		(0.043)
Uncertainty	0.002	0.077			0.006	0.327		
	(0.008)	(0.125)			(0.008)	(0.229)		
Lack of demand			-0.050*	-0.790***			-0.074**	-2.215**

	KIS				LKIS			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
			**				*	*
			(0.009)	(0.143)			(0.009)	(0.262)
ln(Age)	-0.008	-0.210	-0.009	-0.222	-0.026***	-0.968***	-0.027***	-0.979***
	(0.009)	(0.156)	(0.009)	(0.155)	(0.009)	(0.280)	(0.008)	(0.275)
Exporter dummy t-1	0.032***	0.309**	0.031***	0.300**	0.049***	1.154***	0.048***	1.133***
	(0.009)	(0.136)	(0.009)	(0.135)	(0.009)	(0.283)	(0.009)	(0.280)
Industrial group	-0.023**	-0.403**	-0.022**	-0.396**	0.018*	0.541*	0.018*	0.548*
	(0.011)	(0.168)	(0.011)	(0.167)	(0.010)	(0.305)	(0.010)	(0.301)
Patent dummy t-1	0.011	-0.094	0.012	-0.088	0.065***	1.051**	0.063***	1.018**
	(0.014)	(0.187)	(0.014)	(0.186)	(0.017)	(0.419)	(0.017)	(0.416)
Informal protection dummy t-1	0.028***	0.354***	0.027***	0.341**	0.024**	0.540**	0.023**	0.526*
	(0.009)	(0.134)	(0.009)	(0.134)	(0.010)	(0.275)	(0.010)	(0.273)
ln(Size)	0.034***	0.555***	0.033***	0.549***	0.019***	0.528***	0.018***	0.515***
	(0.004)	(0.065)	(0.004)	(0.065)	(0.003)	(0.101)	(0.003)	(0.100)
Subsidy dummy t-1	0.066***	0.744***	0.065***	0.731***	0.068***	1.368***	0.067***	1.348***
	(0.008)	(0.137)	(0.008)	(0.137)	(0.009)	(0.263)	(0.009)	(0.261)
Sales growth	0.022***	0.339***	0.021***	0.332***	0.013**	0.317**	0.012**	0.314**
	(0.004)	(0.065)	(0.004)	(0.065)	(0.005)	(0.131)	(0.005)	(0.131)
Other obstacles	-0.031***	-0.346***	-0.025***	-0.260**	-0.014**	-0.195	-0.006	0.039
	(0.007)	(0.104)	(0.007)	(0.104)	(0.007)	(0.196)	(0.007)	(0.197)
Constant		-5.819***		-5.608***		-11.614***		-10.979***
		(0.770)		(0.763)		(0.996)		(0.977)
N° of observations	11,942	7,919	11,942	7,919	11,702	3,880	11,702	3,880
Log likelihood	-3,990.23	-26,751.98	-3,973.86	-26,736.80	-3,806.35	-15,858.81	-3,770.68	-15,823.30
σ_u	0.758***	2.808***	0.734***	2.769***	0.806***	5.131***	0.778***	5.005***
	(0.052)	(0.120)	(0.052)	(0.121)	(0.053)	(0.235)	(0.053)	(0.234)
ρ	0.365***	0.267***	0.350***	0.262***	0.394***	0.365***	0.377***	0.355***
LR test for Rho	126.762	546.201	114.697	525.103	152.728	478.487	137.003	457.777
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets. Time and industry dummies are included. Columns 1-3-5-7 report marginal effects.

6. Concluding remarks

This paper has revived demand-pull perspectives from the point of view of barriers to innovation and investigated whether perceptions of a lack of demand and of demand uncertainty negatively affect the propensity to invest in R&D and the intensity of the financial effort devoted to this activity.

Our main conjecture is that the size of the destination market and expectations regarding profitability (that is, the perceived lack of demand and of market dynamism) are likely to have impacts other than the mere uncertainty regarding the propensity to engage in R&D and the intensity of that engagement. While the former reflects a general trust in the state of the economy and is, hence, more of a macro-condition that firms need to verify, the latter is a micro-condition concerning the specific characteristics of the product and, hence, the actual user needs that the product is supposed to satisfy. Our claim, for which we provide empirical support, is that a lack of trust in the macro-condition of demand's dynamism represents more of a deterrent for firms to even engage in innovative activities, whereas uncertainty regarding the specific demand and user needs, while still being a deterrent, are likely to be incorporated in the firms' specific R&D plans.

We have found support for this conjecture. From our analysis it emerges that while the perception of an increasing lack of demand has a significant, strong and negative effect on both the decision to invest and the amount of investment in R&D, increasing demand uncertainty does not seem to have any significant effect or to have a weakly significant positive effect (Stein and Stone, 2013). Part of the demand uncertainty might therefore be already "incorporated" in the strategic horizon of firms' decisions when they engage in an intrinsically risky and uncertain activity such as R&D.

These findings contribute to the debate on demand-pull and technology-push approaches in innovation studies from a radically novel perspective, namely, that of barriers to innovation.

The literature on barriers is increasingly important due to its obvious policy relevance. However, much of the scholarship produced to date, with few exceptions, has focused on financial barriers, overlooking other important hindrances that firms might face when deciding to innovate. Overlooking demand-related obstacles – we argue – reflects the dominance of technology-push perspectives and the way the debate between demand-pull and technology-push has been shaped over time (see Di Stefano et al., 2012 for a recent review).

An exhaustive consideration of the policy implications of these findings goes beyond the scope of this paper. However, our results confirm the importance of demand as a strong incentive to innovate. We support the need to foster demand-side innovation policies in the innovation policy agenda (Archibugi and Filippetti, 2011). Although the role of demand is still incipient in innovation policies (Edler and Georghiu, 2007), recent trends show an increase in, and a growing emphasis on, the use of demand-side innovation measures (OECD, 2011; Edler, 2013). These measures may help guarantee markets for new goods and services and complement supply-side innovation policy tools to promote innovation efforts and performance.

Finally, our results show that the lack of demand affects negatively the decision to invest in R&D for the four groups of sectors considered. Although the sectors differ in terms of their innovation dynamics, these results suggest that demand-oriented innovation policies may stimulate R&D in all types of industry. Nevertheless, further research is needed to analyse in greater detail the reaction of individual industries to the lack of demand and the convenience of targeting different sectors with different policy tools.

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APPENDIX

Table A1. The variables: acronyms and definitions.

Dependent variables (Innovative Inputs)	
R&D dummy	Dummy =1 if firm's R&D (both internal and external) expenditures are positive
ln(R&D)	Natural log of the total firm's expenditures in R&D (both internal and external)
Independent variables (control variables)	
ln(Age)	Natural log of the firm's age (calculated as years elapsed since founding)
Exporter dummy	Dummy =1 if the firm have traded in an international market during the three year period; 0 otherwise
Industrial group	Dummy =1 if the firm is part of an industrial group, 0 otherwise
Patent dummy	Dummy=1 if the firm uses patents; 0 otherwise
Informal protection dummy	Dummy=1 if the firm adopts others instruments of protection than patents; 0 otherwise
ln(Size)	Log of the total number of firm's employees
Subsidy dummy	Dummy = 1 if the firm has received public support for innovation; 0 otherwise
Sales growth	Growth rates of sales (calculated by taking logarithmic differences of sales levels)
Other obstacles	Dummy=1 if the firm reports an higher degree of importance (from period t to period t+1) for at least one of the remaining obstacles variables; 0 otherwise
Independent variables (Obstacle demand variables)	
Lack of demand	Dummy=1 if the firm reports an higher degree of importance (from period t to period t+1) for the obstacles variables "it was not necessary to innovate due to the Lack of demand for innovation"; 0 otherwise
Uncertainty	Dummy=1 if the firm reports an higher degree of importance (from period t to period t+1) for the obstacles variables "Uncertain demand for innovative goods or services"; 0 otherwise

Table A2. Robustness check: Dynamic RE probit and tobit estimations with both the demand obstacles variable										
	Whole Sample		LMLt		HMHt		KIS		LKIS	
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)	(9) R&D Dummy	(10) Ln (R&D)
R&D Dummy t-1	0.264***		0.300***		0.216***		0.275***		0.234***	
	(0.005)		(0.009)		(0.012)		(0.011)		(0.010)	
R&D Dummy t_0	0.227***		0.233***		0.181***		0.173***		0.240***	
	(0.008)		(0.015)		(0.017)		(0.017)		(0.016)	
Ln (R&D) t-1		0.696***		0.724***		0.652***		0.715***		0.775***
		(0.010)		(0.017)		(0.018)		(0.020)		(0.032)
Ln (R&D) t_0		0.466***		0.422***		0.299***		0.335***		0.796***
		(0.013)		(0.022)		(0.023)		(0.024)		(0.044)
ln(Age)	-0.003	-0.171**	0.000	-0.052	0.001	-0.094	-0.008	-0.212	-0.027***	-0.987***
	(0.004)	(0.077)	(0.008)	(0.131)	(0.008)	(0.114)	(0.009)	(0.156)	(0.009)	(0.278)
Exporter dummy t-1	0.061***	0.973***	0.082***	1.530***	0.057***	0.991***	0.031***	0.304**	0.049***	1.156***
	(0.005)	(0.086)	(0.009)	(0.166)	(0.010)	(0.161)	(0.009)	(0.136)	(0.009)	(0.282)
Industrial group	0.013***	0.121	0.032***	0.407**	-0.014	-0.268*	-0.023**	-0.401**	0.018*	0.533*
	(0.005)	(0.090)	(0.010)	(0.163)	(0.010)	(0.143)	(0.011)	(0.168)	(0.010)	(0.304)
Patent dummy t-1	0.039***	0.224**	0.050***	0.420**	0.025**	0.110	0.011	-0.092	0.064***	1.032**
	(0.007)	(0.095)	(0.012)	(0.170)	(0.011)	(0.128)	(0.014)	(0.187)	(0.017)	(0.418)
Informal protection dummy t-1	0.032***	0.470***	0.034***	0.493***	0.037***	0.451***	0.028***	0.347***	0.023**	0.522*
	(0.005)	(0.073)	(0.009)	(0.133)	(0.009)	(0.112)	(0.009)	(0.134)	(0.010)	(0.275)
ln(Size)	0.036***	0.572***	0.064***	1.019***	0.049***	0.695***	0.034***	0.554***	0.019***	0.522***
	(0.002)	(0.036)	(0.005)	(0.075)	(0.005)	(0.068)	(0.004)	(0.065)	(0.003)	(0.101)
Subsidy dummy t-1	0.053***	0.567***	0.043***	0.463***	0.034***	0.265***	0.066***	0.739***	0.068***	1.358***
	(0.004)	(0.069)	(0.007)	(0.118)	(0.008)	(0.102)	(0.008)	(0.137)	(0.009)	(0.262)
Sales growth	0.018***	0.315***	0.021***	0.375***	0.013**	0.257***	0.022***	0.337***	0.013***	0.331**
	(0.003)	(0.044)	(0.007)	(0.115)	(0.005)	(0.079)	(0.004)	(0.065)	(0.005)	(0.131)

Demand obstacles	-0.040***	-0.645***	-0.046***	-0.729***	-0.024**	-0.345*	-0.025*	-0.293	-0.056***	-1.660***
	(0.006)	(0.111)	(0.011)	(0.196)	(0.012)	(0.180)	(0.013)	(0.217)	(0.013)	(0.397)
Other obstacles	-0.024***	-0.248***	-0.014**	-0.068	-0.042***	-0.438***	-0.030***	-0.334***	-0.015**	-0.184
	(0.003)	(0.054)	(0.006)	(0.097)	(0.006)	(0.083)	(0.007)	(0.103)	(0.007)	(0.196)
Constant		-8.428***		-10.749***		-4.429***		-5.767***		-11.272***
		(0.348)		(0.699)		(0.671)		(0.768)		(0.988)
N° of observations	54,110	31,558	18,730	10,774	11,736	8,985	11,942	7,919	11,702	3,880
Log likelihood	-18,329.66	-110,278.72	-6,954.99	-38,625.14	-3,442.05	-27,913.23	-3,988.48	-26,751.25	-3,797.46	-15,850.89
σ_u	0.821***	3.339***	0.805***	3.378***	0.890***	2.367***	0.753***	2.802***	0.797***	5.093***
	(0.025)	(0.062)	(0.039)	(0.111)	(0.061)	(0.097)	(0.052)	(0.120)	(0.053)	(0.235)
ρ	0.403***	0.317***	0.393***	0.295***	0.442***	0.276***	0.362***	0.266***	0.388***	0.361***
LR test for Rho	719.478	2,853.464	271.269	920.858	144.563	597.539	123.517	541.750	147.587	471.681
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets. Time and industry dummies are included. Columns 1-3 report marginal effects

Table A3. Robustness check: Dynamic RE probit and tobit estimations with the obstacles variables identifying those firms assessing as highly important the lack/uncertainty of demand (whole sample).

	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)
R&D Dummy t-1	0.263*** (0.005)		0.263*** (0.005)	
R&D Dummy t_0	0.229*** (0.008)		0.214*** (0.008)	
Ln (R&D) t-1		0.695*** (0.010)		0.697*** (0.010)
Ln (R&D) t_0		0.469*** (0.013)		0.447*** (0.013)
Uncertainty (high)	-0.003 (0.004)	-0.075 (0.072)		
Lack of demand (high)			-0.155*** (0.008)	-3.684*** (0.152)
ln(Age)	-0.003 (0.004)	-0.170** (0.078)	-0.001 (0.004)	-0.148* (0.076)
Exporter dummy t-1	0.061*** (0.005)	0.980*** (0.086)	0.058*** (0.005)	0.929*** (0.085)
Industrial group	0.013** (0.005)	0.117 (0.090)	0.012** (0.005)	0.103 (0.089)
Patent dummy t-1	0.039*** (0.007)	0.226** (0.095)	0.038*** (0.006)	0.222** (0.094)
Informal protection dummy t-1	0.033*** (0.005)	0.475*** (0.073)	0.031*** (0.005)	0.450*** (0.073)
ln(Size)	0.036*** (0.002)	0.573*** (0.036)	0.034*** (0.002)	0.558*** (0.035)
Subsidy dummy t-1	0.053*** (0.004)	0.569*** (0.069)	0.050*** (0.004)	0.538*** (0.068)
Sales growth	0.019*** (0.003)	0.316*** (0.044)	0.017*** (0.003)	0.298*** (0.044)
Other obstacles	-0.024*** (0.003)	-0.251*** (0.054)	-0.024*** (0.003)	-0.251*** (0.054)
Constant		-8.498*** (0.349)		-8.020*** (0.342)
N° of observations	54,110	31,558	54,110	31,558
Log likelihood	-18,349.30	-110,295.05	-18,135.34	-109,984.6

	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)
σ_u	0.829***	3.353***	0.800***	3.244***
	(0.025)	(0.062)	(0.024)	(0.062)
ρ	0.407***	0.319***	0.390***	0.306***
LR test for Rho	741.687	2,886.465	690.512	2,734.302
p-value	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets. Time and industry dummies are included. Columns 1-3 report marginal effects.

Table A4. Robustness check: Dynamic RE probit and tobit estimations with the obstacles variables identifying those firms assessing as highly important the lack/uncertainty of demand (manufacturing sectors).

	Low/medium-low tech Sectors				High/medium-high tech Sectors			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
R&D Dummy t-1	0.299***		0.297***		0.215***		0.219***	
	(0.009)		(0.009)		(0.012)		(0.012)	
R&D Dummy t_0	0.236***		0.219***		0.183***		0.171***	
	(0.015)		(0.015)		(0.017)		(0.017)	
Ln (R&D) t-1		0.723***		0.724***		0.651***		0.657***
		(0.017)		(0.017)		(0.018)		(0.018)
Ln (R&D) t_0		0.425***		0.404***		0.301***		0.286***
		(0.022)		(0.022)		(0.023)		(0.023)
Uncertainty (high)	0.000	-0.006			-0.003	-0.090		
	(0.008)	(0.128)			(0.008)	(0.110)		
Lack of demand (high)			-0.186***	-4.163***			-0.110***	-2.553***
			(0.014)	(0.272)			(0.015)	(0.266)
ln(Age)	0.000	-0.054	0.002	-0.018	0.001	-0.092	0.001	-0.088
	(0.008)	(0.131)	(0.007)	(0.129)	(0.008)	(0.114)	(0.008)	(0.112)
Exporter dummy t-1	0.083***	1.539***	0.077***	1.458***	0.058***	0.999***	0.057***	1.000***
	(0.009)	(0.166)	(0.009)	(0.164)	(0.010)	(0.162)	(0.010)	(0.160)
Industrial group	0.032***	0.405**	0.032***	0.424***	-0.014	-0.272*	-0.016	-0.297**
	(0.010)	(0.163)	(0.010)	(0.161)	(0.010)	(0.143)	(0.010)	(0.141)
Patent dummy t-1	0.051***	0.426**	0.047***	0.386**	0.025**	0.109	0.025**	0.119
	(0.012)	(0.170)	(0.012)	(0.168)	(0.011)	(0.128)	(0.011)	(0.127)
Informal protection dummy t-1	0.035***	0.500***	0.033***	0.494***	0.037***	0.452***	0.035***	0.417***
	(0.009)	(0.133)	(0.008)	(0.132)	(0.009)	(0.112)	(0.009)	(0.112)
ln(Size)	0.064***	1.024***	0.060***	0.974***	0.049***	0.694***	0.047***	0.680***
	(0.005)	(0.075)	(0.004)	(0.074)	(0.005)	(0.068)	(0.005)	(0.067)
Subsidy dummy t-1	0.043***	0.460***	0.039***	0.413***	0.034***	0.265***	0.032***	0.245**
	(0.007)	(0.118)	(0.007)	(0.117)	(0.008)	(0.102)	(0.007)	(0.101)
Sales growth	0.020***	0.371***	0.018**	0.342***	0.013**	0.258***	0.013**	0.253***

	Low/medium-low tech Sectors				High/medium-high tech Sectors			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(0.007)	(0.115)	(0.007)	(0.115)	(0.005)	(0.079)	(0.005)	(0.079)
Other obstacles	-0.013**	-0.069	-0.014**	-0.083	-0.042***	-0.438***	-0.042***	-0.440***
	(0.006)	(0.097)	(0.006)	(0.097)	(0.006)	(0.083)	(0.006)	(0.083)
Constant		-10.833***		-10.277***		-4.455***		-4.196***
		(0.702)		(0.688)		(0.673)		(0.658)
N° of observations	18,730	10,774	18,730	10,774	11,736	8,985	11,736	8,985
Log likelihood	-6,962.87	-38,632.12	-6,874.53	-38,506.78	-3,444.01	-27,914.74	-3,417.22	-27,867.77
σ_u	0.813***	3.398***	0.783***	3.280***	0.898***	2.377***	0.854***	2.294***
	(0.039)	(0.111)	(0.038)	(0.110)	(0.061)	(0.097)	(0.060)	(0.097)
ρ	0.398***	0.297***	0.380***	0.284***	0.446***	0.278***	0.422***	0.264***
LR test for Rho	279.635	934.860	262.300	891.461	148.547	604.306	132.658	556.862
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets. Time and industry dummies are included. Columns 1-3-5-7 report marginal effects.

Table A5. Robustness check: Dynamic RE probit and tobit estimations with the obstacles variables identifying those firms assessing as highly important the lack/uncertainty of demand (services sectors).

	KIS				LKIS			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
R&D Dummy t-1	0.275***		0.272***		0.232***		0.230***	
	(0.011)		(0.011)		(0.010)		(0.010)	
R&D Dummy t_0	0.175***		0.167***		0.244***		0.229***	
	(0.017)		(0.016)		(0.016)		(0.016)	
Ln (R&D) t-1		0.714***		0.711***		0.771***		0.767***
		(0.020)		(0.020)		(0.032)		(0.032)
Ln (R&D) t_0		0.336***		0.327***		0.803***		0.762***
		(0.024)		(0.024)		(0.044)		(0.043)
Uncertainty (high)	-0.004	-0.121			-0.002	-0.024		
	(0.009)	(0.135)			(0.010)	(0.284)		
Lack of demand (high)			-0.133***	-2.841***			-0.162***	-5.660***
			(0.016)	(0.295)			(0.016)	(0.491)
ln(Age)	-0.008	-0.212	-0.007	-0.183	-0.026***	-0.973***	-0.025***	-0.944***
	(0.009)	(0.156)	(0.009)	(0.154)	(0.009)	(0.280)	(0.008)	(0.274)
Exporter dummy t-1	0.031***	0.304**	0.029***	0.271**	0.049***	1.156***	0.045***	1.056***
	(0.009)	(0.136)	(0.009)	(0.135)	(0.009)	(0.283)	(0.009)	(0.279)
Industrial group	-0.023**	-0.406**	-0.022**	-0.394**	0.018*	0.541*	0.016*	0.478
	(0.011)	(0.168)	(0.011)	(0.167)	(0.010)	(0.305)	(0.010)	(0.301)
Patent dummy t-1	0.011	-0.090	0.009	-0.096	0.065***	1.053**	0.067***	1.126***

	KIS				LKIS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(0.014)	(0.187)	(0.014)	(0.186)	(0.017)	(0.419)	(0.016)	(0.414)
Informal protection dummy t-1	0.028***	0.353***	0.027***	0.337**	0.024**	0.531*	0.021**	0.465*
	(0.009)	(0.134)	(0.009)	(0.134)	(0.010)	(0.275)	(0.010)	(0.272)
ln(Size)	0.034***	0.553***	0.033***	0.543***	0.019***	0.526***	0.018***	0.524***
	(0.004)	(0.065)	(0.004)	(0.064)	(0.003)	(0.102)	(0.003)	(0.100)
Subsidy dummy t-1	0.066***	0.747***	0.065***	0.731***	0.068***	1.364***	0.065***	1.315***
	(0.008)	(0.137)	(0.008)	(0.136)	(0.009)	(0.263)	(0.009)	(0.260)
Sales growth	0.022***	0.339***	0.021***	0.330***	0.013**	0.323**	0.011**	0.279**
	(0.004)	(0.065)	(0.004)	(0.065)	(0.005)	(0.132)	(0.005)	(0.130)
Other obstacles	-0.031***	-0.341***	-0.030***	-0.337***	-0.014**	-0.183	-0.013*	-0.127
	(0.007)	(0.103)	(0.007)	(0.103)	(0.007)	(0.196)	(0.007)	(0.195)
Constant		-5.762***		-5.527***		-11.491***		-10.694***
		(0.770)		(0.760)		(0.994)		(0.973)
N° of observations	11,942	7,919	11,942	7,919	11,702	3,880	11,702	3,880
Log likelihood	-3,990.17	-26,751.76	-3,955.99	-26,704.35	-3,806.61	-15,859.82	-3,744.65	-15,784.26
σ_u	0.759***	2.808***	0.741***	2.752***	0.806***	5.130***	0.786***	4.961***
	(0.052)	(0.120)	(0.051)	(0.120)	(0.053)	(0.235)	(0.052)	(0.232)
ρ	0.365***	0.267***	0.354***	0.260***	0.394***	0.364***	0.382***	0.352***
LR test for Rho	126.781	545.907	122.008	529.891	152.299	477.609	144.365	457.093
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets. Time and industry dummies are included. Columns 1-3-5-7 report marginal effects.

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University of Sussex
Falmer, Brighton, BN1 9SL, UK
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